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Space Tactical Imaging

I'm here to tell you about our vision for tactical optical imaging from space. Before explaining our vision, I need to define what we mean by tactical. We call a space system "tactical" when it's designed primarily to be useful to field commanders leading a military operation. Most optical imaging from space today has been designed with national leadership and strategic reconnaissance in mind, not the field commander. So what are the key attributes of a system supporting the field commander?

First, it should be available at short notice. The battlefield commander wants to know his environment in the next few minutes or hours, as well as the next few days. He must be able to task the sensor quickly and receive the imagery quickly. This could be enabled by large constellations of small, cheap satellites, small constellations of higher-flying satellites, or by satellites on demand. In all cases, the battlefield commander would have tasking authority.

Second, the imagery must be persistent. A single picture every few days is not good enough. The battlefield changes take place in minutes, not in days. As an extreme example, sometimes the commander will want the equivalent of a live video feed. Again, this could be enabled by a couple of different satellite constellations, each with their own technical challenges.

Third, it should be flexible enough to provide not only high resolution imaging, but also broad area surveillance. Sometimes the commander wants an image with better than 1 meter resolution. But just as important sometimes is the capability to provide information on enemy forces over areas that are hundreds of kilometers square. Today we do this job with airborne radars, and we are looking at space-based radars to do the same function. But doing it with optics offers a different set of phenomena to do the mission, and may be able to do it as a second function on an existing sensor.

Why space? Many of these requirements can be fulfilled with aircraft. Indeed, DARPA has been at the forefront of building long duration, unmanned aircraft to give the commander a persistent, taskable asset for tactical use. The reason to consider space lies in its enduring advantages: access to denied regions, minimal logistics footprint in theatre, and relative immunity from enemy forces.

There are plenty of technical challenges in meeting these objectives. The challenges occur at the component level, the spacecraft level, and the "constellation" level. I'd like to tell you some of our ideas for how to enable these objectives.

We are pursuing the idea of a Low Cost Tactical Imager, known as LCTI. LCTI will be a small, inexpensive, high resolution, day or night imaging spacecraft able to be launched on demand, anytime, anywhere, into any orbit to support the tactical warfighter. LCTI will also provide the first-ever ability to task the spacecraft and downlink the imagery in the same pass to support near real time imaging and targeting, perform rapid bomb damage assessment, and defeat denial and deception techniques.

LCTI will need to demonstrate novel technologies to reduce the spacecraft mass by half and the telescope by a factor of ten to enable launch on an air launched booster such as the Pegasus or RASCAL. Today's imaging spacecraft require years of lead time to manufacture the primary optic. LCTI will reduce the build time to a month using just-in-time manufacturing to enable short notice call up and eliminate the need for spare spacecraft.

Fortunately, there are a couple of key enabling technologies. First, we cannot afford either the dollars or the time to grind out monolithic mirrors, and probably can't afford the weight or size on the launch vehicles, either. We are looking at lightweight optics that might be able to change the way we think of optical imaging such as Fresnel lenses, nanolaminates, membranes, and even one based on a core of light bulbs. All offer us the chance to get area densities on the order of 1-10 kg/m2, roughly 10 times lighter than anything being built today.

These technologies have challenges. Fresnel lenses have been built to limited size, limited bandwidth, and limited field of view. We are looking at ways to improve all three. Better fabrication techniques are needed to achieve finer spacing of the Fresnel zones, and to make a larger lens. Chromatic corrector plates are needed to make the lens work over a large range of wavelengths.

Similarly, membrane mirrors with good optical smoothness have been built with diameters of 10-20 cm, with some technique needed to apply and hold the correct optical curvature figure. Techniques include dynamic holography using spatial light modulators or MEMS-based rubber mirrors, electrostatic control of the membrane, stressed membranes, and piezoelectric membranes. We also need to build larger membranes and there are plenty of manufacturing challenges associated with that.

If we can build a decent optical instrument using either of these techniques, we can envision significant reductions in weight, size, cost, and time to make sensors, and enable both rapid on-demand launch and constellations of many satellites. Furthermore, if membrane mirrors can be successfully built to tens of meters in diameter, then we may also have a way to field optical sensors at medium earth orbits. Because of orbital dynamics, satellites at this altitude stay above a certain target region for much longer, giving the commander the persistence of coverage that is desired for tactical application.

The bottom line is that next fiscal year, we anticipate kicking off one or a few programs in this area of space tactical imaging. We are looking for your ideas to help us make a revolution in space-based optical imaging that will put new capability in the hands of the warfighter. Keep your ear to the ground for a BAA.